WHAT ARE S0 (0) GALAXIES?

Sidney van den Bergh

Dominion Astrophysical Observatory, Herzberg Institute of Astrophysics, National Research Council of Canada, 5071 West Saanich Road, Victoria, BC, V9E 2E7, Canada

sidney.vandenbergh@nrc-cnrc.gc.ca

Received _____; accepted _____

ABSTRACT

Among early-type galaxies with almost circular isophotes E0 and E1 galaxies are, at 99.3% significance, more luminous than face-on objects classified as S0 (0) and S(0) (1). This result supports the view that rotation and "diskiness" are more important in the outer regions of faint early-type galaxies than they are for more luminous galaxies of very early morphological type.

Subject headings: galaxies: classification

1. INTRODUCTION

Hubble (1936, p.44) introduced the classification type S0 to bridge the gap between objects of types E7 and Sa. Galaxies that are morphologically intermediate between ellipticals and spirals have also been referred to as "lenticulars" by de Vaucouleurs (1959). A detailed discussion of the morphology of S0 galaxies is given in Sandage (1961, p.10) and in Sandage & Bedke (1994, Vol.1, p.7). Not unexpectedly S0 galaxies, on average, appear more flattened than E galaxies. Following Hubble this flattening f may be defined as $f = 10(a\text{-}b)/a$, where a and b are the major and minor axis diameters, respectively. In the convention adopted by Sandage & Tammann (1981) an elliptical of flattening f will be called an Ef, whereas an S0 galaxy of the same flattening is denoted S0 (f). The physical difference between elliptical and lenticular galaxies is that S0 galaxies contain an old disk, whereas ellipticals do not. It often becomes difficult to unambiguously distinguish between these two classes of objects when either (1) only a small fraction of the light originates in the disk, or (2) if the disk is viewed almost pole-on. This effect is clearly seen in the Coma cluster (Abraham & van den Bergh 2004) where most flattened, and hence presumably edge-on, early-type galaxies were classified as S0s, whereas those objects that have more

circular isophotes are mostly classified as ellipticals. Nevertheless, some nearly circular [S0 (0) or S0 (1) in the notation of Sandage & Tammann (1981)] galaxies are classified as S0 rather than E0 or E1. What are these almost circular objects that Sandage and Tammann (1981) classify as being of type S0 (0)?

2. THE NATURE OF S0 (0) GALAXIES.

The classifications of galaxies given in *A Revised Shapley -Ames Catalog of Bright Galaxies* (Sandage & Tammann 1981) represent the gold standard of galaxy classification because they were almost all based on inspection of photographic images obtained with large reflectors, that were classified in a uniform fashion by highly experienced galaxy morphologists. The Shapley-Ames Catalog (in which $H_o = 50$ km s^{-1} Mpc^{-1} was assumed) contains 45 ellipticals of types E0 + E1 which have $< M_B^o >$ = -21.19 ± 0.15 and 14 S(0) (0) plus S0 (1) galaxies for which $< M_B^o >$ = -20.25 ± 0.30. The mean luminosity difference between E0 and E1 galaxies on the one hand, and S0 (0) and S0 (1) galaxies on the other, is found to be 0.94 ± 0.34 mag. However, this estimate of the mean error in the difference between the mean luminosities makes the unwarranted assumption that both E0 +E1 and the S0 (0) plus S0 (1) galaxies in the Shapley-Ames Catalog have Gaussian luminosity distributions. It is therefore better to use a non-paramentric test to assess the significance of the difference in the mean luminosities of nearly circular E and S0 galaxies. Such a test is provided by the data in Table 1 which shows the number of nearly circular E and S0 galaxies that are brighter (or fainter) than $< M_B^o >$ = -20.5. For the data in Table 1 Chi-sqared = 7.2 which, for one degree of freedom, yields an a-priori probability of only 0.7% for the hypothesis that nearly round ellipticals and nearly circular S0 galaxies have parent populations with the same luminosity distribution. [A Kolmogorov-Smirnov test yields a probability of 11% that these two samples were drawn from the same parent

population.] In other words the present data strongly suggest that E0 + E1 galaxies are systematically more luminous than S0 (0) and S0 (1) galaxies. This means that assigning a round early-type galaxy to the E or S0 class may be regarded as a crude form of luminosity classification. Whereas the morphological luminosity classification of spiral galaxies (van den Bergh 1960abc) was based on the characteristics of their spiral arms, the distinction between E and S0 galaxies is based on the existence (or absence) of a faint amorphous envelope Sandage (1961, p.11).

The galaxy luminosities given by Sandage & Tammann (1981) are on the B_T system of the RC2 Catalog of de Vaucouleurs et al. (1976). However, because integrated magnitudes depend on the outer profiles of galaxies, there is a small systematic difference between absolute magnitudes of galaxies on the B_T system of de Vaucouleuers et al. and those on the B_{26} system of Sandage & Visvanathan (1978). According to Sandage & Tammann (1981, p.7) $(B_{26} - B_T)$ = -0.12 mag for E's and $(B_{26} - B_T)$ = -0.03 mag for S0 galaxies. However, these effects are seen to be an order of magnitude smaller than the observed systematic differences between the luminosities of nearly spherical E and S0 galaxies. In other words the systematic difference between the luminosity distributions of E and S0 galaxies is too large to be attributed to systematic differences between the luminosity profiles of these two types of objects. Inspection of Fig. 22 of van den Bergh (1997) shows that S0 galaxies are not only fainter than E0 galaxies but they are, on average, also fainter than galaxies of types Sa and Sb. This shows that the luminosity differences between spiral, S0, and E galaxies are not primarily due to the systematic changes of galaxy luminosity along the Hubble classification sequence.

3. CONCLUSION.

Among very early-type galaxies with almost circular isophotes some are called ellipticals [E0 + E1] and others are classified as lenticulars [S(0) (0) and S(0) (1)]. It is shown that the objects that were classified as ellipticals are, on average, almost one magnitude more luminous than those that are called S0. This suggests that the dichotomy between round ellipticals and face-on S0 galaxies (which appear to have extended amorphous envelopes) represents a crude form of luminosity classification for early-type galaxies. Physically this result confirms that rotation and "diskiness" are more important in the outer regions of faint early-type galaxies than they are in more luminous early type objects. This conclusion is consistent with earlier work by Davies et al. (1983), Capaccioli et al. (1990) and by Rix, Carollo & Freeman (1999).

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Table 1. Luminosity versus type for round early-type galaxies in the Shapley-Ames catalog

Types	$M_B^o \leq -20.50$	$M_B^o > -20.50$
S0 (0) + S0 (1)	6	8
E0 + E1	36	9